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Technical Attachment

The Seasonal Influence of Pacific Sea Surface Temperature Oscillations Upon Continental U.S. Tornado Climatology for Tornadoes of F2 Intensity and Greater

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Introduction

The El Niño - Southern Oscillation (ENSO) has been in the news for nearly two decades as a major influence upon national weather patterns. At times it seems coverage of the phenomenon is overly dramatized, with bad storms that occur during a warm ENSO receiving more attention than those that occur at other times. However, the climatic influence of this Pacific sea surface temperature (SST) oscillation is statistically observable in national temperature and precipitation data.

In recent years, another Pacific Ocean SST oscillation has gained attention, the Pacific Decadal Oscillation (PDO). Simply stated, the PDO is a warming and cooling of north Pacific SSTs, with a cycle of decades. In contrast, the ENSO is a tropical Pacific SST oscillation which usually takes only a few years to complete. Thus, several ENSO cycles can occur during one PDO cycle. Recent and ongoing research has identified the influence of the PDO upon world climate (Mantua, et al. 1997).

Since ENSO and the PDO can be compared to national temperature and precipitation data, they can likewise be compared to historical storm data. While typical severe weather and tornado climatologies for a given area are useful, there are a few questions to ask. Is there more information to be mined from the data? Is every spring in tornado alley equally risky? How might the Pacific SST oscillations influence tornado climatology? An analysis of U.S. tornado records, relative to occurrences of specific combinations of PDO and ENSO SST anomalies, suggests that the Pacific has an identifiable influence on seasonal tornado climatology, specifically for tornadoes of F2 intensity and greater.

1. The Data

The data for this study were constructed using information available on the Internet. The U.S. tornado records for tornadoes of F2 intensity and greater (F2+) was found at the National Climatic Data Center (NCDC) Storm Events webpage:

http://www4.ncdc.gov/cgi-win/wwcgi.dll?wwEvent~Storms

The monthly PDO anomaly data were found at Nathan Mantua's indices directory:

ftp://ftp.atmos.washington.edu/mantua/pnw_impacts/INDICES/

Monthly ENSO anomalies (using NINO3.4) were also found at Mantua's site, up to April of 2000, while more recent data were found at the National Center for Environmental Prediction website of ENSO anomalies:

ftp://ftp.ncep.noaa.gov/pub/cpc/wd52dg/data/indices/sstoi.indices

Seasonal averages of ENSO, the PDO, and the state-by-state F2+ data were calculated for the four meteorological seasons: winter (December-February), spring (March-May), summer (June-August), and fall (September-November), from spring 1950 to fall 2002.

Tornadoes of F2 category were chosen to be the lower limit of intensity for two reasons. First, an analysis of strong tornadoes was desired. Second, it was judged that a disproportionate risk existed for a minor wind damage event to be erroneously categorized as a weak tornado, especially in older records.

Some of the "per state" data were slightly modified in consideration of state size, as some eastern states are no bigger than a western county. Thus, some eastern states were combined to form larger unit areas in order to improve the representativeness of the results. Vermont, New Hampshire, Massachusetts, Connecticut, and Rhode Island were grouped to form one unit area, while Maryland, Delaware, and New Jersey formed a second unit area. These two unit areas are similar in size to the single states that surround them.

2. Methodology and Analysis

A data set for each season was created, with the Pacific oscillation data and the state tornado data placed in parallel columns in a Quattro Pro spreadsheet. In this way, each row of data shared the same season/year.

From the data, two parameters were computed for each state or area:

a) the average frequency of F2+ tornadoes per season (i.e., the total number of F2+ tornadoes divided by the number of seasons), and

b) the percentage of all seasons which had at least one F2+ tornado (i.e., the number of seasons with at least one F2+ event divided by the number of seasons).

These two values were multiplied for each state/area to arrive at a parameter which represents the "normal" F2+ tornado climatology for each state and season. Thus, the impact of relatively rare tornado outbreaks upon any given state's seasonal average, an impact especially felt with bare tornado-per-year averages, is lessened. The impact of the seasonal probability of occurrence is included, which reflects the "proneness" of a state to experiencing F2+ tornadoes in any given season. Together, a) and b) provide an easily calculated variable that enables comparison of an overall state-by-season climatology with an oscillation-relative climatology.

To determine the oscillation-relative F2+ tornado climatologies, each season's data was divided into four smaller groups, based on the following oscillation combinations: warm PDO/warm ENSO, warm PDO/cool ENSO, cool PDO/warm ENSO, and cool PDO/cool ENSO (or, P+N+, P+N-, P-N+, and P-N-, respectively). Additional calculations were performed to find the four oscillation-relative F2+ "normals" per season per state (or per unit area).

These oscillation-relative tornado normals were then compared with the corresponding seasonal normal, and a percent of seasonal normal was calculated for the oscillation-relative normals. It was decided that any oscillation-relative normal that fell within one-third of the overall seasonal normal (0.6667 to 1.3333) would be considered *near normal*. Percent of normal values above 1.3333 were considered to reflect an *active* oscillation-relative F2+ climatology, while values below 0.6667 were considered to reflect an *inhibited* oscillation-relative F2+ climatology. Thus, an active normal value exceeds an inhibited normal value by a ratio of at least 2-to-1.

3. Results and Discussion

Results of this analysis are best viewed graphically in Figs. 1-4. For each season, four national maps, depicting the P+N+, P+N-, P-N+, and P-N- climatologies, reveal the findings of this study. States or unit areas shaded in red represent those with active F2+ tornado climatologies; those in blue represent inhibited F2+ tornado climatologies; and those in white are near normal. Yellow represents special cases in which there where no F2+ tornadoes observed.

During the winter, the vast majority of F2+ tornadoes on the West Coast occurred in a P+N+ Pacific regime (Fig. 1a), the same regime that resulted in inhibited production across Texas and Louisiana. A P-N+ regime (Fig.1c) correlated with an active winter across Texas and Louisiana, thus, we observe that during a warm ENSO winter, it is the PDO anomaly that may best guide one's expectations concerning strong tornadoes in Texas and Louisiana. In the Southeast and the Ohio Valley Fig. 1d indicates that a P-N- regime correlated with an active F2+ winter, while a P+N- regime correlated with an inhibited F2+ winter (Fig. 1b). Thus, during a cool ENSO winter in those areas, the PDO anomaly again provides interesting clues concerning the F2+ potential.

In the spring, the vast majority of F2+ tornadoes in the Northwest occurred when the Pacific oscillations were out of phase, either P+N- or P-N+ (Figs. 2b and 2c). For the area generally referred to as tornado alley, a surprising lull appears to occur during a P+N- regime (Fig. 2b). In New England, a P-N+ regime (Fig. 2c) stands out among the others when it comes to a more active F2+ tornado climatology.

During the summer, much of the nation is at or below normal in a P+N- regime (Fig. 3b), while much of the nation is at or above normal in a P-N- regime (Fig. 3d). New Mexico's oscillation-relative F2+ tornado climatology is above normal during a P-N+ regime (Fig. 3c), and below normal during any other regime; thus we see that a general summertime normal of F2+ tornadoes in New Mexico may not actually provide a meaningful climatological expectation, while the oscillation-relative climatologies do.

In the fall, when the mid-South typically enters its second severe weather season, there was a noted lull in the observed F2+ tornado climatology during a P-N+ regime (Fig. 4c). New England received most of its autumn activity in a P-N- regime (Fig. 4d). West of the Rockies, most activity occurred in a warm ENSO (Figs. 4a and 4c), while little activity occurred in a cool ENSO (Figs. 4b and 4d), all with seemingly little influence from the PDO.

While the results of this study are not without a degree of randomness, this is primarily manifest during seasons that are not typically characterized by tornado activity. For example, when the seasonal normal was already very low, a relatively unimpressive low oscillation-relative normal may still easily exceed the very low seasonal normal score by more than 33 percent.

4. Conclusion

It was assumed before the study that if the state-by-state results of active and inhibited oscillation-relative F2+ tornado climatologies were randomly distributed across a map, then the study would prove inconclusive. However, if states with similar oscillation-relative F2+ tornado climatologies were to be regionalized or grouped together, such patterns would be suggestive that the Pacific SST anomalies (which prompt changes in continental weather patterns as seen in temperature and rainfall records) do recognizably influence severe weather climatology.

The latter appears to be the case, as summarized in the previous discussion section, and as seen graphically in Figs. 1-4. Thus it may be concluded that consideration of Pacific SST oscillation cycles is useful in assessing climatological impacts on occurrence of severe weather, at least as represented by reports of F2+ tornadoes.

Acknowledgments

Special thanks go to Bill Murrell, forecaster at WFO Shreveport, Louisiana, who assisted in the production of the charts used in Figs. 1-4.

Reference

Mantua, Nathan J., Steven R. Hare, Yuan Zhang, John M. Wallace, and Robert C. Francis, 1997: A Pacific Interdecadal Climate Oscillation with Impacts on Salmon Production, *Bull. Amer. Meteor. Soc.,* **78**, 1069-1079.

Figures 1. Winter (DJF)

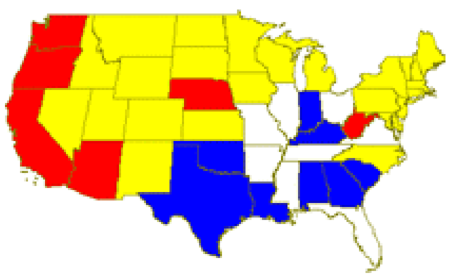

Fig. 1a. PDO warm, ENSO warm.

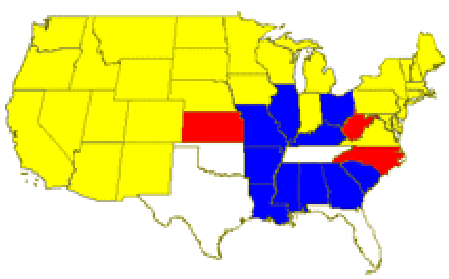

Fig. 1b. PDO warm, ENSO cool.

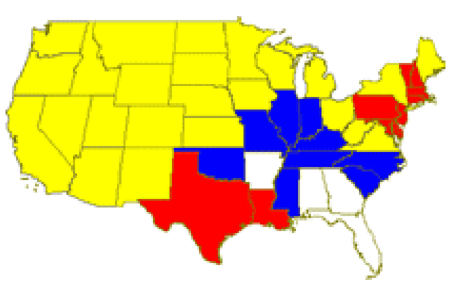

Fig. 1c. PDO cool, ENSO warm.

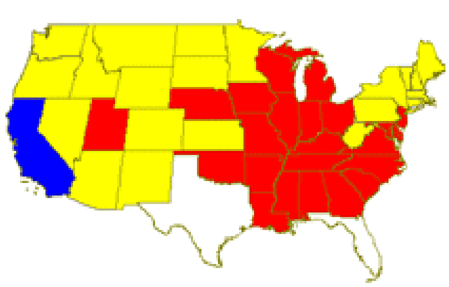

Fig. 1d. PDO cool, ENSO cool.

Figures 2. Spring (MAM)

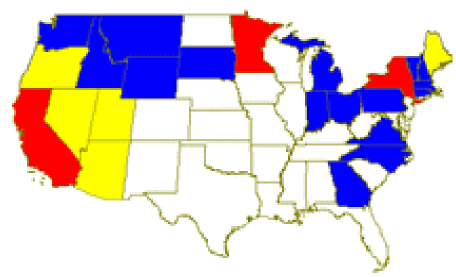

Fig. 2a. PDO warm, ENSO warm.

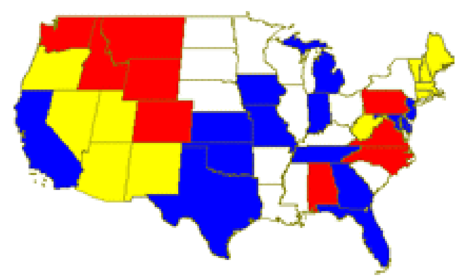

Fig. 2b. PDO warm, ENSO cool.

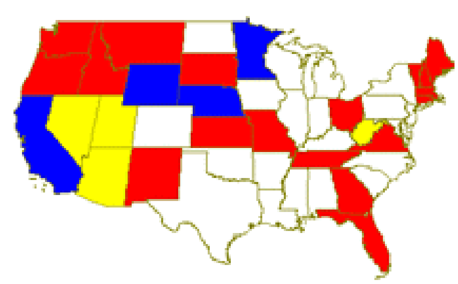

Fig. 2c. PDO cool, ENSO warm.

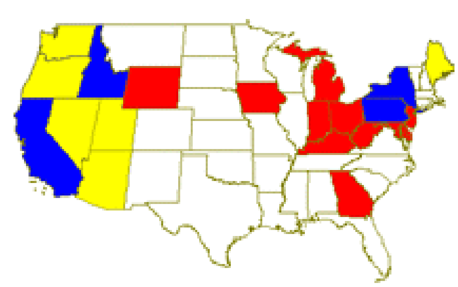

Fig. 2d. PDO cool, ENSO cool.

(Blue: Inhibited. Red: Active. White: Near Normal. Yellow: No F2T+s observed.)

Figures 3. Summer (JJA)

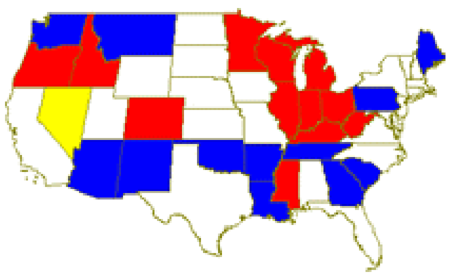

Fig. 3a. PDO warm, ENSO warm.

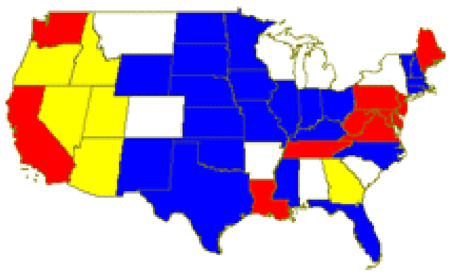

Fig. 3b. PDO warm, ENSO cool.

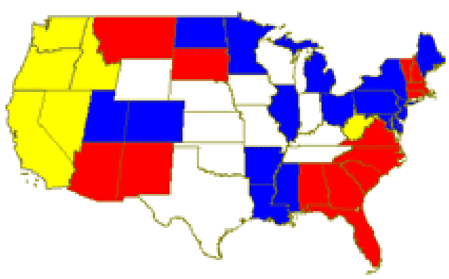

Fig. 3c. PDO cool, ENSO warm.

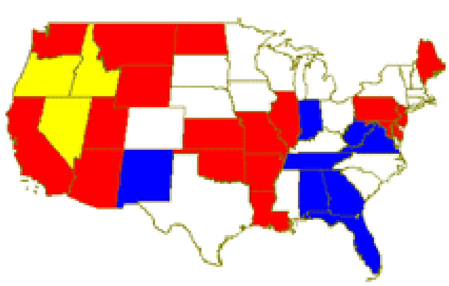

Fig. 3d. PDO cool, ENSO cool.

Figures 4. Autumn (SON)

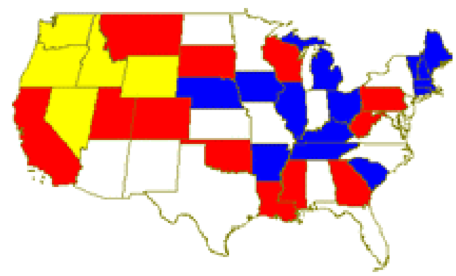

Fig. 4a. PDO warm, ENSO warm.

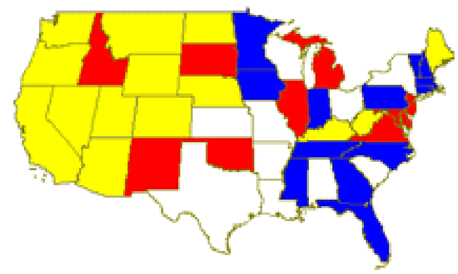

Fig. 4b. PDO warm, ENSO cool.

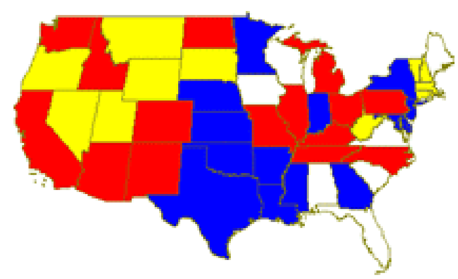

Fig. 4c. PDO cool, ENSO warm.

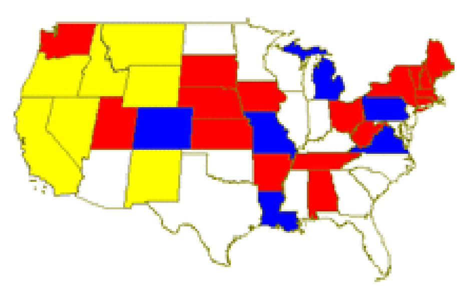

Fig. 4d. PDO cool, ENSO cool.

(Blue: Inhibited. Red: Active. White: Near Normal. Yellow: No F2T+s observed.)